The moderating role of social networks within the radical innovation process: a multidimensionality of human capital-based analysis

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Abstract: Knowledge, or intellectual capital, and innovation continue to be key areas subject to rapid change in the current environment. The complexity of the relationship between knowledge and innovation leads to the in-depth study of more specific linkages. Intellectual capital is divided into human, organisational and social capital. This paper attempts to provide empirical evidence relating to the relationship between human capital and radical innovation, along with social networks. Using data collected via a questionnaire, our hypotheses were tested empirically in a sample of 251 Spanish technology-intensive manufacturing firms. The paper provides new, empirically-based insights into the study of radical innovation by adopting a research framework which is built upon the intellectual capital-based view of

the firm, based on the multidimensionality of human capital. The main results show the positive and statistically significant role of human assets in radical innovation, and, regarding a moderating role, indicate the existence of a substitution effect between one of the human capital components – experience and abilities – and social networks.

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1   Introduction

The new competitive dynamic generated by the changing socioeconomic environment leads us to pay close attention to technological innovation as a key factor in business success (Galende, 2006; Molina-Castillo and Munuera-Alemán, 2009; Salman and Saives, 2005), using intangible resources and capabilities owned by a firm, that is, its intellectual capital.

The evolution of economic activity targeted towards the development of the so-called knowledge society (Dean and Kretschmer, 2007; Drucker, 2007) is directly related to the creation, use and exchange of knowledge. Within this domain, approaches such as the resource-based view (Amit and Schoemaker, 1993; Barney, 1991; Peteraf, 1993; Wernerfelt, 1984) and the knowledge-based view of the firm (Conner and Prahalad, 1996; Grant and Baden-Fuller, 1995; Kogut and Zander, 1992; Nonaka, 1994) have achieved prominence in the analysis of new economic contexts, since they acknowledge and reflect the importance of intangible factors for achieving business success.

Nevertheless, there are still problems associated with these perspectives, regarding the conceptualisation, assessment and measurement of intangible resources and capabilities. The work reported here focuses on the intellectual capital-based view (ICV) (Reed et al., 2006) because it offers a way to overcome some of the limitations associated with the resource-based view. For example, the resource-based view has been criticised for its lack of specificity, which has caused questions to be raised "as to its status as a legitimate theory, and makes it difficult to design and test empirically" [Reed et al., (2006), p.868]. To address this issue these authors propose a pragmatic resolution, the so-called ICV. Moreover, intellectual capital has an increasingly important role as a strategic resource in business competition (Dean and Kretschmer, 2007).

The ICV identifies different elements within intellectual capital, with the majority of ICV scholars distinguishing three components: human capital, structural/organisational capital and social capital (Bontis, 1998; Brooking, 1996; Morris and Snell, 2011; Subramaniam and Youndt, 2005; Sveiby, 2000; among others).

However, this current study focuses attention on human capital and social capital because they are central to a firm's innovation processes, and, as such, are of increasing relevance, given the growing importance of innovation within the firm (Dean and Kretschmer, 2007). Human capital is the core and precursor of the rest of the intellectual capital elements (Wu et al., 2007), and its role in competitive advantage would benefit from being better understood through a more detailed investigation and articulation of the construct (Wright and McMahan, 2011). Social capital is also important because relationships between a firm's employees are fundamental to the way they exchange and combine their knowledge (Nahapiet and Ghoshal, 1998). Considering human capital alongside the social context, which can have an impact on individuals (Wright and McMahan, 2011), provides an interesting lens through which to consider how organisations achieve competitive advantage. Moreover, according to Macpherson and Holt (2007), there is a lack of research on the use of particular knowledge resources and how context influences this issue. According to Rodan and Galunic (2004, p.543), social capital exists within links among people and, therefore, "is a function of the social network within which an individual is embedded". So, taking into account the importance of social networks, as well as Nahapiet and Ghoshal's (1998) consideration of one of the social capital dimensions, the structural dimension which refers to models of connections

among people, the present article is focused on this important aspect of social capital: social networks.

Following the above arguments, and due to the scarcity of specific empirical studies which examine the relationship between knowledge and technological innovation from an ICV (i.e. Subramaniam and Youndt, 2005; Wu et al., 2008), the main aim of this paper is to analyse empirically the influence of different human capital dimensions, together with one aspect of social capital – social networks – on radical innovation.

Specifically, this study attempts to provide empirical evidence around the technological innovation process, paying particular attention to two important intangibles, human capital and social networks, because despite the fact that there are a small number of empirical studies which analyse similar issues, those empirical studies tend to focus on a very narrow set of causal relationships. Specifically, some studies do not examine certain interactions or moderating effects (Hervas-Oliver et al., 2011) which could be required in order to understand the phenomenon. Hence, we attempt to shed light on more complex models of these two intellectual capital aspects, considering their interaction, relating to radical innovation. Results of the work should help inform managers regarding the requirements for engaging in radical innovation.

In addition to requiring more empirical studies, research on intellectual capital continues to require more theoretical development (Cabrita and Bontis, 2008; Serenko and Bontis, 2013), specifically relating to the role of human capital (Wright and McMahan, 2011). Based on the work of Martín et al. (2010), we understand that human capital is a multidimensional component. This last issue has rarely been addressed by other studies (i.e. Martínez-Torres, 2006; Morris and Snell, 2011; Wu et al., 2008), but is important in order to obtain empirical support focused on the innovation processes of a firm. Thus, this investigation attempts to deepen understanding of the separate dimensions of human capital.

Therefore, this study will focus on finding answers to the following questions: How do the different human capital dimensions influence radical innovation? Could social networks play a key role within that relationship? Would social networks change the effects found?

The paper is structured into four parts. The first presents the theoretical background, considering several approaches appropriate for analysing the firm's internal and intangible factors and conceptualising the main concepts of the study. Also, a statement of our hypotheses is presented. Next, details of the population, sample and methods are discussed, as well as measures developed for the study. Then, our hypotheses are tested and the results obtained are presented. The final section contains the discussion, conclusions, implications, limitations and future research directions.

2   Theoretical background and hypotheses

2.1   Human capital, social networks and radical innovation

Intellectual capital can be defined as a set of intangible resources and capabilities, related to different categories of knowledge (individual, organisational or inter-organisational), which can provide a firm with competitive advantage (Subramaniam and Youndt, 2005).

Owing to the fact that intellectual capital is a broad concept, this study focuses on two important aspects which make it up: human capital and social networks – the last one as

the main dimension of social capital. There are two reasons why this work emphasises these two elements. First, as mentioned above, there is a need for in-depth analysis of human capital which is at the core of and is a precursor to the rest of the intellectual capital elements. Further, employees' relationships which are at the heart of social capital are fundamental to the exchange and combination of knowledge which lead to innovation. Second, both human capital and social capital have been attracting increasing attention in the literature in recent years (Dean and Kretschmer, 2007).

Regarding human capital, Wu et al. (2007) assert that it has a strategic role to play in order for firms to achieve a competitive advantage. Many authors who examine this concept adopting the ICV (Brooking, 1996; Reed et al., 2006; Steward, 1998; Sveiby, 2000; among others) understand human capital as knowledge owned by people, including their abilities, motivation, experiences, education and training. This diverse range of factors indicates that human capital may be multidimensional.

Following this line, according to Martín et al. (2010) and Subramaniam and Youndt (2005), we may distinguish three main aspects owned by employees:

1   education and training as basic knowledge, which lays the foundations for the rest of the individual elements, and is explicit knowledge because it is gained through formal mechanisms

2   more advanced knowledge, such as abilities and experiences, which improves day-by-day, that is, it is tacit knowledge gained as a result of learning on the job

3   people's mood or attitude, such as motivation.

Studies of human capital usually focus on these aspects separately. For example, James (2000) characterised human capital by education and training; Pike et al. (2005) considered different capabilities and learning, which are represented by experience and abilities; and, finally, satisfaction has been considered independently by many studies. Within the intellectual capital literature, motivation is an aspect very close to satisfaction (Roos and Roos, 1997), a relevant issue within the innovation process (Perez-Cano and Quevedo-Cano, 2006).

Thus, this work defines the human capital of a firm as knowledge and skills embedded in its staff, which are applied to carry out activities within the organisation, trying to achieve a competitive advantage.

With respect to social capital, in general terms, it consists of knowledge resources embedded within, available through and derived from a network of relationships (Nahapiet and Ghoshal, 1998). This work focuses on personal and informal relationships among employees which are not predetermined by the firm, understanding them from a sociological perspective. In this sense, Macpherson and Holt (2007) point out that social capital is made up of informal and social contacts. Specifically, the social network is the "degree of contact and accessibility of one with other people" [Chow and Chan, (2008), p.464], so close relationships which lead to the development of strong links (Newell et al., 2004), of higher quantity or greater frequency, as well as enhanced levels of communication, are aspects considered within social networks.

Numerous authors show the importance of innovation and its role within the firm, economy and wider society (Salman and Saives, 2005; Schumpeter, 1942; Tushman and Nadler, 1986), reflecting many existing points of view around the concept of 'innovation'. The present study, adhering to the underlying idea of Tödtling et al.'s

(2009) work, understands that innovation is the result of a process by which a firm, based on its intellectual assets, creates a new idea that will be marketed.

In addition, it is necessary to distinguish among different types of innovation because each kind requires different management approaches (Hurmelinna-Laukkanen et al., 2008). This study adopts the classification which distinguishes between radical and incremental innovation, because in a complex and dynamic environment, such as exists currently, it is helpful to understand that the more radical the innovation, the easier will be the ensuing business growth, success and survival. We focus on radical innovation because mere improvement of current products, services or production processes is insufficient to ensure a firm's viability in dynamic and changing environments (Rosenkopf and Nerkar, 2001). Radical innovation can be defined as that whose technological characteristics or intended uses differ significantly from those of one previously produced (OECD, 2006).

2.2 *Hypotheses*

Darroch and McNaughton (2002) and Subramaniam and Youndt (2005) stated that existing literature should provide empirical evidence with respect to the relationship between intellectual capital and innovation. Furthermore, it is necessary to offer more complex models around this question (Hervas-Oliver et al., 2011).

Innovation generated and developed by the firm's human capital is one of the most relevant and valuable sources for a knowledge-intensive firm (Edvinsson and Sullivan, 1996). In this regard, other authors, including Boer and During (2001) and Damanpour (1991), put forward the thesis that the personnel's knowledge, capabilities, experiences, abilities, intelligence and education are key drivers of the innovation process.

On the other hand, relationships among members of an organisation make knowledge creation easier (Zupan and Kase, 2007), highlighting the role of social networks within the innovation process. Swart (2006) asserted that members will use their knowledge in order to develop relationships within the group, facilitating the creation and enhancement of innovative capabilities or knowledge. Specifically, Kratzer et al. (2008) stated that the structure of informal networks of teams in R&D projects defines the opportunities potentially available to create new knowledge.

Taking into account possible links between social capital and innovation, Nahapiet and Ghoshal (1998) suggested that bringing together those with diverse knowledge, experience and opinions, to share and exchange information between parties, can lead to enhanced levels of innovation. Hence, close networks act as facilitators of innovation-oriented tasks (Moran, 2005) and communication facilitates knowledge creation (Boutellier et al., 2008). Moreover, Boutellier et al. (2008) highlighted that ease of access to knowledge and intensity of information exchange are important factors in the generation of an innovation.

Following these arguments, this work presents two hypotheses with the aim of shedding more light on the issue. Thus, starting from the general thesis that human capital is a source of technological innovation, we put forward arguments in support of the relationships among human capital components, along with social networks, and radical innovation.

Employees contribute to firm development and progress by means of their individual knowledge. Thus, those firms with high levels of human capital, in terms of diversity of educational and functional experience or motivation (Damanpour, 1991; Hayton, 2005;

Rost, 2011), will realise better and more radical innovation results because that diversity promotes the search for knowledge, helping to achieve innovation, and involves a wide cognitive level, making the generation of new knowledge easier. Indeed, those brighter and more skilled employees, and those with more experience, have a greater likelihood of encouraging the questioning of prevailing norms and the development of new ways of thinking (Subramaniam and Youndt, 2005).

Furthermore, recognising that networks may develop sustainable human capital within the firm (Macpherson and Holt, 2007), if those individual characteristics are combined through appropriate social networks, the innovation results probably will be more positive, since it is essential that team members communicate effectively within the innovation process (Qui et al., 2009). Thus, where open communication takes place and there are strong levels of interaction it is easier to combine respective expertise to deliver effective innovation results. So, it is beneficial to develop strong links among employees (Newell et al., 2004), which are achieved through close relationships (Chow and Chan, 2008), in order to deliver enhanced, more radical innovation results.

This is due to the fact that when employees have close ties and interaction among them improves, deals are faster and develop with fewer problems, people are more productive and have a greater potential to generate new ways, or changes in the way, of creating knowledge, products and processes (Chow and Chan, 2008; Moran, 2005; Swart, 2006; Wu et al., 2008). Sometimes employees' new ideas may need to be combined with one another to attain radical breakthroughs (Subramaniam and Youndt, 2005).

Therefore, we propose the following hypotheses:

Hypothesis 1   Human capital –

      a   education and training

      b   experience and abilities

      c   motivation –

      influences radical innovation positively.

Hypothesis 2   Social networks moderate the relationship among the three components of human capital –

      a   education and training

      b   experience and abilities

      c   motivation –

      and radical innovation.

3 Methodology

3.1 Population, sample and methods

From the SABI database[1], we obtained a total of 1,270 firms which met the following criteria:

1   they are high and medium-high technology manufacturing firms

2   they have 50 or more employees

3   they are Spanish firms.

Regarding the first criterion, we focus on those firms which are based on knowledge because they have a strong dependence on intellectual capital (Johnson et al., 2002). Moreover, Leitner (2005) pointed out that high and medium-high technology industries are strongly focused on intangible factors. On the other hand, some authors, such as King and Keithaml (2003) and Rouse and Daellenbach (1999), assert that selected firms should belong to a homogeneous industry in order to avoid different effects derived from environmental factors.

In addition, with respect to firm size, we focus on high and medium-high technology manufacturing firms with 50 or more employees as they may have a sufficiently diverse stock of human capital and social networks to investigate in the context of radical innovation. This allows us to explore 5.5% of Spanish technology firms in the high and medium-high categories.

The next step was to collect data and, to do this, we designed a questionnaire (seven-point Likert scale, see Appendix) to investigate valuable and unique competences of the firm which are not available from secondary sources (Newbert, 2008) but are of importance since they can lead to competitive advantage (King and Zeithaml, 2003). This method is recommended by Zahra and Covin (1993) in order to collect data of this kind, where it is necessary to develop specific items within the measurement of intangible factors to explore key variables about which firms tend to keep information secret. Before finalising the questionnaire design, four academic experts on intangible factors, intellectual capital and innovation were interviewed. Thus, in line with their main common recommendation, we included 'with respect to your competition' within some questions to make it easier for respondents to answer by providing an appropriate reference point/benchmark against which to judge aspects of their organisation (King and Zeithaml, 2003).

At this point, it is important to highlight that the questionnaire respondents were senior managers because the research focused on several areas of activity within the firm. A senior manager was selected on the basis that they would have an overview of activities across multiple departments within their organisation and be aware of competitors against whom they were being asked to compare their organisation in a number of respects. In 2009, the questionnaire was piloted with ten organisations which met the selection criteria, which enabled checks to be made that questions were clear and respondents were able to complete sections on diverse activities across their organisation.

In addition, to reduce possible common method bias derived from using one informant, the measurement of the independent and dependent variables was separated by using a sequential separation in order that the measurement of the independent variables was not connected with or related to the measurement of the dependent variable (Podsakoff et al., 2003). Moreover, Harman's single-factor test has been applied in order to check if there is a common method bias. As can be seen in the Appendix, a single factor did not emerge from the analysis, so artificial response bias was not assumed to exist in the data. The factor solution produced five factors that account for 40.439%, 12.152%, 9.375%, 8.284%, and 5.571% of the variance, respectively.

The questionnaire was administered as a telephone survey[2], which also allowed any clarification to be offered by the interviewer. A total of 251 firms took part in the study, representing a response rate of 19.76%, with a sampling error of +/–5.5% for a 95% confidence level.

3.2   Measures

From a wide review of the literature we designed, on the one hand, measures for the two main constructs of our research (human capital and social networks), considering several dimensions which make up human capital, and, on the other, we considered the dependent variable (radical innovation). In addition, we took into account firm size, firm age and CNAE-93 codes (high and medium-high technology manufacturing firms: CNAE 24, 29, 30, 31, 32, 33, 34, 35) as control variables because these characteristics may influence innovation.

With respect to human capital, we attempted to obtain information relating to employees' education and training (James, 2000; Snell and Dean, 1992; Wu et al., 2008; among others), employees' experience and abilities (Lepak and Snell, 2002; Subramaniam and Youndt, 2005; Reed et al., 2006; among others) and employees' motivation (Carmeli and Tishler, 2004; Chen et al., 2004; Huselid, 1995; among others), using seven items to gather data on these three dimensions (see Appendix). The social networks variable was measured with three items relating to informal personal interactions (Chen et al., 2008; Chow and Chan, 2008; Wu et al., 2008) (see Appendix). Radical innovation (Chen et al., 2004; Hayton, 2005; Subramaniam and Youndt, 2005; among others) was also measured by three items (see Appendix). These three variables are subjective, continuous and are measured by a seven-point Likert scale.

Finally, we used the number of employees, on a log scale, to control for firm size effect. Firm age was measured in years, from the date of the firm's establishment. Due to the fact that our sample is composed of manufacturing firms which belonged to several sectors, we included dummy variables for each CNAE code. Thus, the two first variables are objective and continuous, and the CNAE codes take the values 0/1.

4   Results

Data processing was carried out in two stages using SPSS 21.0. The first used exploratory factor analysis (EFA) in order to identify the proposed configuration of human capital, because it was considered as a multidimensional construct, and the second used regression analysis in order to test our hypotheses. Key linear regression assumptions, such as normality, multicollinearity, auto-correlation and homoscedasticity, were tested in order to identify any problem. All of the test results were satisfactory. Specifically, correlations among variables, as well as variance inflation factors (VIFs), were run in order to check for issues regarding multicollinearity. No problems were observed because correlation coefficients between independent variables are not larger than 0.8 (Field, 2009) (see Table 1). In fact, regarding human capital components, there is no correlation because a varimax orthogonal rotation was applied. In addition, VIFs' values were under 10 (see Table 3), which also confirms that there are no multicollinearity concerns (Diamantopoulos and Winklhofer, 2001). Furthermore, possible univariate and multivariate outliers were checked and it was not necessary to omit any case from the sample.

The reasons for carrying out an EFA are as follows:

1   to reduce the number of items of human capital to broader components with the aim of summarising information and understanding it better

2   to identify different dimensions which make up this capital, in an attempt to achieve a deeper level of analysis compared with other studies.

In order to test the appropriateness of using the EFA, we need to pay attention to the KMO index, the Barlett's test significance level and the matrix determinant value. These indexes should have values higher than .7, less than .05 and a value close to 0, respectively (Hair et al., 2004).

We also consider Cronbach's alpha coefficients to determine the reliability level of each variable. According to Hair et al. (2004), these coefficients should be close to .7, to confirm that the measures utilised are valid and internally consistent. In addition, to ensure validity, the square roots of the average variance extracted (AVE) for each variable are also studied and included along the diagonal of the correlations matrix (see Table 1). According to Fornell and Larcker (1981), those values should be higher than off-diagonal elements.

In the following discussion, we present the data regarding human capital, social networks, and radical innovation. As was stated above, human capital is studied using seven items and, once the varimax orthogonal rotation is applied in order to achieve a better fit within EFA, they were gathered on three dimensions (Table 2), achieving the following satisfactory results: the KMO index = .750, the Bartlett's test significance level = .000, the matrix determinant value = .072, and all loadings are higher than .7. Moreover, human capital factors have a percentage of explained variance of 75.860. So, the proposed theoretical structure of human capital has been confirmed.

The first factor, 'education and training' (E&T), consists of knowledge acquired through higher education and specific training received by the employees of a firm. Its percentage of explained variance is 31.089, and the Cronbach's alpha value is .815, exceeding the required reliability level. Furthermore, the square root of the AVE is higher than the off-diagonal elements with a value of 0.833. The second factor, 'motivation' (Mot), refers to employees' motivation, including their satisfaction and commitment to their firm, because these employees will be those most motivated to achieve planned goals. Its percentage of explained variance is 23.590, and the Cronbach's alpha value is .720, exceeding the required value. In addition, the square root of the AVE is higher than the off-diagonal elements, with a value of 0.678. The third factor, 'experience and abilities' (E&A), includes knowledge acquired over time through employees' practice and intrinsic abilities. Its percentage of explained variance is 21.182, and the Cronbach's alpha value is .665, achieving a level very close to .7. The square root of the AVE is also higher than the off-diagonal elements, with a value of 0.661.

Social network (Net) is made up of three items focused around links among employees, including the building of links to exchange ideas and information, the maintenance of close relationships, and engagement in constructive discussions around challenges they are facing. Its Cronbach's alpha value is .832, exceeding the value mentioned above. Also, the square root of the AVE is higher than the off-diagonal elements with a value of 0.868. Finally, radical innovation was also measured using three items. Again, in this case, it met the required reliability level, with a Cronbach's alpha value of .793, and the square root of the AVE was higher than the off-diagonal elements (0.950).

Table 1 Correlations matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Size (log)	1														
2 Age	.086	1													
3 CNAE 24	.055	.068	1												
4 CNAE 29	-.096	.004	-.387**	1											
5 CNAE 30	-.032	-.032	-.068	-.069	1										
6 CNAE 31	-.044	-.005	-.260**	-.265**	-.046	1									
7 CNAE 32	-.037	-.107	-.150*	-.153*	-.027	-.103	1								
8 CNAE 33	-.105	.066	-.096	-.098	-.017	-.066	-.038	1							
9 CNAE 34	.222**	-.110	-.214**	-.218**	-.038	-.147*	-.084	-.054	1						
10 CNAE 35	-.022	.074	-.196**	-.199**	-.035	-.134*	-.077	-.050	-.110	1					
11 Social networks	.073	-.109	-.018	-.014	.084	-.023	-.016	-.077	.038	.058	**.868**				
12 Education and training	.040	.034	.056	-.122	.168**	.038	-.005	.096	-.022	-.031	.241**	**.833**			
13 Motivation	.047	.041	.153*	-.059	.019	-.035	-.046	-.097	-.041	.024	.457**	.000	**.678**		
14 Experience and abilities	.024	-.063	-.105	.001	.100	.014	.048	-.003	.053	.013	.274**	.000	.000	**.661**	
15 Radical innovation	.007	.025	.102	.010	.108	.022	.008	-.015	-.076	-.158*	.469**	.411**	.222**	.266**	**.950**

Notes: **Correlation is significant at the .01 level (bilateral)
*Correlation is significant at the .05 level (bilateral)
The square roots of the AVE are along the diagonal (in bold)

Table 2   Human capital EFA

Human capital items	Component		
	1 E&T	*2* Mot	*3* E&A
HC2: Training inside the firm	**.910**	.156	.034
HC1: Employed resources in training activities	**.866**	.301	.048
HC3: Employees with university degree	**.708**	.034	.282
HC6: Employee satisfaction index	.189	**.835**	.172
HC7: Employee commitment index	.167	**.826**	.248
HC4: Employees with appropriate experience	.167	.117	**.865**
HC5: Employees with valuable abilities	.076	.376	**.749**
% Explained variance	31.089	23.590	21.182
% Accumulated variance	31.089	54.679	75.860
Cronbach´s α	.815	.720	.665

Notes: Extraction method: principal components.
 Rotation method: varimax with Kaiser normalisation.
 Rotation has converged after five iterations.

Once the dimensions of human capital, social network and radical innovation had been determined, several multiple regression models were developed with the aim of testing our hypotheses. According to the multiple linear regression rules, we analysed the influence of human capital together with social networks on radical innovation (see Table 3). The Durbin-Watson value indicates that the residues are independent (values close to 2) and the statistical F values show a significant linear relationship between radical innovation, and the rest of the variables, showing the statistical validity of the proposed models. In addition, R squared values of all regression models are acceptable because they are higher than 8% for $\alpha = 0.01$ and 5% for $\alpha = 0.05$ (Hair et al., 2004).

Model 1 (M1) is the baseline and only includes the control variables – firm's size (log), firm's age and CNAE dummies – and the moderating variable – 'social network' (Net), finding that social network has a significant effect on radical innovation in our sample. Then, in order to examine the first hypothesis, in Model 2 (M2) all dimensions of human capital are added and two of them – 'education and training' (E&T) and 'experience and abilities' (E&A) – have a positive and significant statistical influence on radical innovation, supporting partially hypothesis 1 (sub-hypotheses 1a and 1b). In particular, the dimension 'education and training' has the greatest effect ($\beta = 1.259$, $p < .01$) on radical innovation, followed by the dimension 'experience and abilities' ($\beta = .738$, $p < .01$). The dimension 'Motivation' (Mot) is not statistically significant, so the sub-hypothesis 1c is not supported. This means that those firms, which have employees with high levels of education, training, experience and abilities, will achieve better radical innovation results.

Table 3 Regression analysis results on radical innovation

Control, moderating and independent variables	Dependent variable: radical innovation				
	M1	M2	M3	M4	M5
Firm size (log)	−.082	−.128	−.132	−.126	−.117
	(1.093)	(1.095)	(1.096)	(1.095)	(1.096)
Firm age	.325	.254	.251	.254	.239
	(1.064)	(1.078)	(1.078)	(1.078)	(1.079)
CNAE 24	**1.352*****	**1.240*****	**1.222*****	**1.246*****	**1.233*****
	(2.922)	**(2.963)**	**(2.992)**	**(2.968)**	**(2.964)**
CNAE 29	**1.103*****	**1.123*****	**1.116*****	**1.132*****	**1.067*****
	(2.953)	**(2.954)**	**(2.959)**	**(2.964)**	**(2.979)**
CNAE 30	**.519****	.258	.246	.259	.263
	(1.124)	(1.165)	(1.176)	(1.165)	(1.165)
CNAE 31	**.951*****	**.824*****	**.817*****	**.825*****	**.852*****
	(2.268)	**(2.278)**	**(2.283)**	**(2.278)**	**(2.285)**
CNAE 32	**.627****	**.545****	**.551****	**.554****	**.527****
	(1.549)	**(1.554)**	**(1.557)**	**(1.564)**	**(1.557)**
CNAE 33	**.416***	.246	.249	.247	.210
	(2.633)	(1.274)	(1. 275)	(1.274)	(1.284)
CNAE 34	.452	.412	.405	.419	.382
	(2.036)	(2.039)	(2.042)	(2.045)	(2.046)
Net	**1.900*****	**1.289*****	**1.297*****	**1.311*****	**1.217*****
	(1.036)	**(1.586)**	**(1.593)**	**(1.647)**	**(1.628)**
E&T		**1.259*****	**1.245*****	**1.264*****	**1.299*****
		(1.163)	**(1.180)**	**(1.168)**	**(1.177)**
Mot		.231	.244	.251	.265
		(1.379)	(1.394)	(1.428)	(1.388)
E&A		**.738*****	**.727*****	**.730*****	**.720*****
		(1.133)	**(1.145)**	**(1.141)**	**(1.136)**
E&T*Net			.106		
			(1.082)		
Mot*Net				.082	
				(1.177)	
E&A*Net					−.369*
					(1.093)
Model summary					
R^2	.282	.395	.396	.396	.403
Adjusted R^2	.252	.362	.360	.360	.368
Change in R^2	–	**.113*****	.001	.001	**.008***
Std. error of the estimate	3.34677	3.09057	3.09522	3.09570	3.07568
Durbin-Watson	-	-	2.138	2.140	2.153
F-statistic	9.412***	11.908***	11.045***	11.037***	11.401***

Notes: ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$ (FIVs' values)

Finally, Models 3 (M3), 4 (M4), and 5 (M5) include each interaction term among human capital dimensions and social networks – E&T*Net; Mot*Net; and E&A*Net, respectively – for testing hypothesis 2, which considers the moderating effects of social networks on the relationship of each human capital component and radical innovation. The results show that the first two interactions, E&T*Net and Mot*Net, are not statistically significant, so the sub-hypotheses 2a and 2c are not supported. Only the coefficient of the interaction term (E&A*Net), between 'experience and abilities' and social networks (M5), is statistically significant, so the finding supports hypothesis 2b. The coefficient is negative ($\beta = -.369$, $p = .071$), indicating a substitution rather than complementary effect. Specifically, those firms characterised by an intense social network will not increase their radical innovation performance considerably by enhancing their employees' experience and/or abilities. This means that when firms have highly experienced and skilled employees a powerful social network is not as important and influential. Only when a social network is not present within the organisation, or is weak, will additional levels of employees' experience and abilities positively affect radical innovation. Figure 1 shows the described substitution pattern.

Figure 1   The moderation of the effect of 'experience and abilities' on radical innovation, by social networks
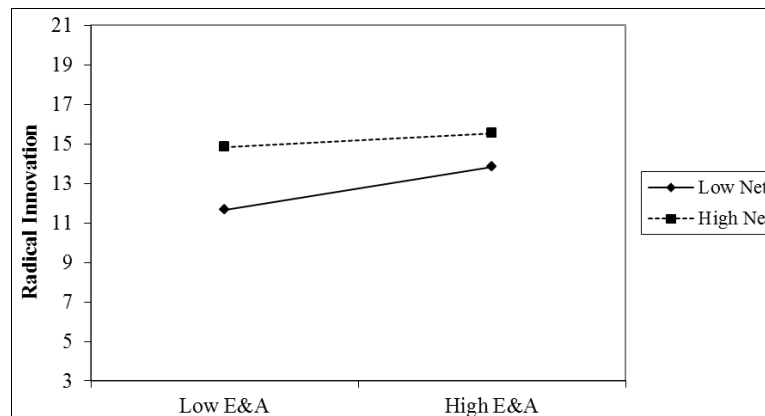
5   Discussions and implications

This research contributes interesting empirical results, providing a more complete structure of human capital, as well as offering support for some more complex relationships between human capital components, along with social networks and radical innovation. This work builds on that of researchers including Tseng and Goo (2005), regarding the importance of knowledge and innovation in the contemporary knowledge-based economy; Wright and McMahan (2011), who show the need for a better understanding of the human capital construct; Cabrita and Bontis (2008) and Serenko and Bontis (2013), who highlight the importance of theoretical and empirical development of intellectual capital; Subramaniam and Youndt (2005), with respect to the scarcity of empirical studies that examine the relationship between knowledge and technological innovation from an ICV perspective; Darroch and McNaughton (2002) and

Tödtling et al. (2009), who point out the lack of empirical research and consequent dearth of in-depth evidence regarding the relationship between the different elements of intellectual capital and types of innovation; and Dean and Kretschmer (2007), who focus on the growing relevance of human and social capital studies.

Using the ICV perspective, we found that human capital assets, as well as social networks, could be important sources of radical innovation within high and medium-high technology Spanish manufacturing firms. Specifically, we considered different dimensions of human capital in order to compare the importance of each together with social networks in the context of a specific type of innovation, radical innovation, because different types of innovation will require the use and management of different resources within the firm (McEvily et al., 2004), and may require specific types of knowledge (Tödtling et al., 2009).

Thus, in line with our expectations, we identified, empirically, three dimensions within human capital: 'education and training', 'motivation' and 'experience and abilities', the first being the most interesting, so this dimension may be a key factor for carrying out effective radical innovation. According to Hegde and Shapira (2007, p.355), "the continuous upgrading of skills – referring to training- is essential to sustaining a high-quality workforce able to adapt to changing market demands and to ensure that innovations can be effectively introduced and implemented". Hence, it appears important to have a strong foundation of this kind of knowledge related to particular tasks to be effective in innovation.

With respect to interactions among components of human capital and the social network, the last one only moderates the relationship between 'experience and abilities' and radical innovation, showing a substitution effect against Qui's et al. (2009) argument. This may be due to the fact that those employees who have high levels of experience and abilities do not need support from their colleagues, while those employees with less of this kind of knowledge will need more help when undertaking challenging new product or process development work. So, firms focused on achieving radical innovation, and with highly experienced and skilled employees, could substitute knowledge derived for informal relationships among their employees, and vice versa.

On the other hand, neither 'motivation' nor 'education and training' have an interaction effect with the social network. According to Vitell et al. (2010), there are some characteristics of work which are predictors or determinants of individual behaviour. Therefore, considering that commitment and satisfaction are attitudes of employees, we could view the social network as one of the antecedents of employees' motivation instead of being a moderating variable. Finally, taking into account that knowledge derived from experience and abilities is tacit knowledge acquired through 'learning by doing' (Hitt et al., 2001), and education and training is explicit knowledge derived through formal mechanisms, it is interesting to analyse the different results regarding interaction effects. Unlike knowledge derived from experience and abilities, which in some ways is a form of knowledge linked to personal relationships, because it is usually gained at the same time as people maintain informal relationships, education and training may be viewed as knowledge acquired in a way different from those relationships.

In the professional domain, managers need tools to evaluate their management activities and the outcomes of their firm's innovation activities. Thus, due to changing and complex consumer demands, which have led to development of an increasing range of radical innovations, it is relevant to emphasise the importance of the innovation

process in the current business landscape, where knowledge as well as its applications are key elements in achieving and maintaining business success.

Therefore, an empirical study which focuses on these characteristics provides valuable evidence regarding what managerial actions should be taken by firms when dealing with their intellectual capital, identifying the knowledge and processes which offer the highest potential for different types of successful innovation. The findings of this work suggest that human capital is a key factor in order to achieve radical innovation, with important aspects including education, training, experience and abilities. Thus, firms should place importance on hiring people with higher levels of education and experience, and on providing training courses for their employees to improve their abilities. Moreover, if a firm does not have highly experienced and skilled employees it could attempt to influence social networks by providing an environment which encourages communications among employees within the organisation and facilitates the emergence of informal relations, in order to achieve enhanced radical innovation results.

There are several limitations in this study. First, we collected subjective, primary data, but it would be interesting to consider objective data, as well, and combine them. In addition, answers were obtained from the same respondent within each firm, which could introduce a problem of common method bias, in spite of having applied Harman's single factor test. However, according to Chang et al.'s (2010, p.180) recommendations, "including a non-linear interaction term in the model is likely to reduce CMV [common method variance] because such a complex relationship is, in all likelihood, not part of the respondents' theory-in-use". In this sense, our relationships include moderator effects through social networks. Secondly, the findings of this empirical research cannot be generalised to all types of industry, since our sample only drew on high and medium-high technology manufacturing sectors. For this reason, implications for managerial practice may only be obtained for these industries. Finally, the dynamic nature of factors which affect firms has not been taken into account to reflect how firms and activities change over time. This is a consequence of using a cross-sectional survey instead of carrying out a longitudinal study.

Therefore, for future research, it would be interesting

1   to work with objective, secondary data, combining them with primary data obtained in this study

2   to analyse the same interactions in another industry, since sources of innovation may differ depending upon the sector (Vega-Jurado et al., 2008)

3   to analyse other interaction effects among human capital dimensions and other aspects of social capital or, even, among other intellectual capital components

4   to undertake an in-depth study exploring links and whether those connections create value for a firm from a technological innovation process viewpoint, as Oh et al. (2004) and Subramaniam and Youndt (2005) have proposed in their work.

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Notes

1   'Sistema de Análisis de Balances Ibéricos' (SABI) is an economic-financial database which includes around 550,000 Spanish firms and 67,000 Portuguese firms. Each record includes the following information: contact, activity description, national and international economic activities codes (in this article CNAE-93 is used), corporate body, number of employees, profit and loss account and start-up date.

2   Telephone survey was 15 minutes long, including other questions the results of which are not considered in this paper.

Appendix

Questionnaire items

Seven-point Likert scale: '1 = strongly disagree', '7 = strongly agree'

- Human capital:
  - HC1 My company allocates resources (money, time, etc.) to employee training to a greater extent than in my competitors.
  - HC2 In my company, the percentage of people who receive training is higher than in my competitors.
  - HC3 In my company, the percentage of people with a superior degree (bachelor, engineer, masters, etc.) is higher than in my competitors.
  - HC4 The experience that our employees have is appropriate to carry out satisfactorily their work.
  - HC5 Our employees' own abilities are widely considered the best in our industry.
  - HC6 Generally speaking, our employees are satisfied in the company.
  - HC7 Employees feel a strong sense of commitment and loyalty to the company.

- Social networks:
  - Net1 In my company, there are employees and/or teams who build informal network relationships in order to exchange idea and information about the development of new products.
  - Net2 In my company, there are employees and/or teams who maintain good close relationships among them.
  - Net3 In my company, there are employees and/or teams who discuss issues with each other in a constructive way when things go wrong.

- Radical innovation:
  - Rad1 In general, the number of completely new innovations developed by my company in the last three years is higher than my competitors' one.
  - Rad2 My company develops innovations that turn into obsolete or drastically change prevailing/existing ones.
  - Rad3 The percentage of sales on radical innovations (completely new) introduced in the last three years is higher than my competitors' one.

Table A1   Harman's single-factor test

Measures	Component				
	1	*2*	*3*	*4*	*5*
HC1	.239	.853	.138	.193	.051
HC3	−.077	.634	.276	.189	.200
HC2	.159	.904	.097	.075	.053
HC4	.123	.183	.045	.100	.893
HC5	.262	.021	.264	.315	.672
HC6	.210	.216	.077	.809	.136
HC7	.295	.155	.110	.773	.203
Net1	.818	.068	.140	.165	.104
Net3	.833	.088	.172	.187	.087
Net2	.749	.209	.171	.222	.223
Rad1	.331	.351	.699	−.018	.051
Rad2	.055	−.016	.818	.213	.164
Rad3	.261	.369	.772	.012	.066